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A DIGITAL COMPUTER PROGRAM FOR DETER-
MINING THE PULSE TO PULSE RADAR
CROSS SECTION ON A DYNAMIC TARGET

Frederick Elwood Meyett

United States Naval Postgraduate School



THESIS

A Digital Computer Program
For Determining the Pulse to Pulse
Radar Cross Section on a Dynamic Target

by

Frederick Elwood Meyett, Jr.
Lieutenant, United States Navy
B. S., United States Naval Academy, 1963

Thesis Advisor:

Robert L. Miller

June 1971

Approved for public release; distribution unlimited.

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Submitted in partial fulfillment of the
requirements for the degree of

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Thesis
M 573
C.1.

ABSTRACT

This paper describes the design and use of SIGMA, a computer program for the calculation of radar cross section of a dynamic target on a pulse to pulse basis, using the MK 25 Fire Control Radar. The program is written specifically for use on the Scientific Data Systems 9300 computer in FORTRAN IV, but is readily adapted to other data processing systems. The input data base is composed of magnetic tape recordings of instrumented radar range and signal strength. Outputs include target cross section and range, and mean cross section and range in printed tabular listing, in graphical form, and on digital magnetic tape.

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I. INTRODUCTION

Radar cross sections for various simple geometric objects have been calculated and experimentally verified. Cross sections for more complex targets such as fixed and rotary wing aircraft have been measured. This is usually done by constructing a scale model of the target. The model is then placed in an anechoic chamber and illuminated with appropriate RF energy at a frequency scaled to the model. The aspect of the model with respect to the sensor is then varied and the backscattered energy is recorded. From this data cross section as a function of aspect and frequency is obtained.

The examination of cross sections of geometric objects is useful in an academic approach to diffraction phenomenon, but bears little significance to the engineering of a radar system. Measurement of cross sections of models is at best, a first-order approximation to the determination of back-scatter cross section. The model is static and rests in a controlled environment. A dynamic target does not show a smooth, modelled shape. Further, backscatter is modified by turbine engine modulation and changes in diffraction of the wave fronts due to airfoil control surfaces and fuselage vibration. Since target size has a pronounced effect on the determination of radar system performance, it is then necessary that cross section be measured on dynamic targets.

One method for dynamic measurement of cross section uses a ground-based fire control radar. Prior to tracking the target to be measured, the radar system is calibrated by tracking a 6-inch metal sphere lofted by a helium-filled balloon. Automatic Gain Control (AGC) voltage and

range are recorded. This calibration permits many of the parameters in the radar range equation to be considered as a single term. Immediately following the calibration, the target is tracked and AGC voltage and range are recorded. Comparing ranges to target and sphere for equal AGC voltages, cross section for the target can be calculated. While this method is a definite improvement over static measurement, disadvantages still exist. The AGC circuit serves to integrate the target data such that only mean cross sections can be calculated. Instantaneous data is lost.

By recording the pulse to pulse variation in signal strength and computing a cross section for each pulse, much statistical data can be gained. For example, a spectral analysis of cross section variation could be performed. With a radar properly instrumented for recording azimuth and elevation data, correlation of the spectral lines with pattern recognition could produce target signatures. The computer program SIGMA described by this paper performs the first of these operations. The received signal is converted to radar cross section on a pulse to pulse basis. The output data is then placed in a form conducive for statistical analysis by digital techniques. Although the program was written specifically for use on the Scientific Data Systems 9300 computer, it is readily adapted to other user oriented systems.

II. THEORY

The concepts for measurement of radar cross section on a pulse to pulse basis are similar to those outlined by Cunningham [Reference 1]. The fire control radar that is used in the measurement is first calibrated by tracking a target of known radar cross section, in this case a metallic sphere. Since the sphere presents a constant aspect and its cross section may be calculated, a functional relationship between radar range and signal strength can be found. Armed with this relationship and known constant sphere cross section, the unknown target is tracked, and signal strength and range are recorded. Radar cross section for the target is ultimately found by forming a ratio of radar range equations. Each range equation may be reduced to a relatively simple form if measurement of the target immediately follows calibration, and atmospheric effects are neglected. By proceeding in this manner, system parameters such as transmitted power, noise figure, integration improvement factor, system losses and antenna gain, may be assumed to remain constant. Let this then be the case as described and further, let α represent those terms which remain constant between calibration and measurement. Then the simplified form of the radar range equation is written as:

$$R^4 = \frac{\alpha \sigma}{S} \quad (1)$$

where: R = radar range, meters

S = detected signal, watts

σ = radar cross section, meter²

α = constant, meter²-watts

In the MK 25 Fire Control Radar System, the voltage output from the box-car circuit is readily accessible and more conveniently measured than actual signal power at the receiver input. The functional relationship between this voltage and signal power is not linear because of the circuitry involved, but may be generally written:

$$S = f(V)V \quad (2)$$

where V = boxcar circuit output voltage.

Equation (1) may be rewritten:

$$R^4 = \frac{\alpha \sigma}{f(V)V} \quad (3)$$

and further, let:

$$\beta(V) = \frac{\alpha}{f(V)} \quad (4)$$

then Equation (1) becomes:

$$R^4 = \frac{\beta(V)\sigma}{V} \quad (5)$$

or:

$$\beta(V) = \frac{VR^4}{\sigma} \quad (6)$$

and:

$$\beta(V_S) = \frac{V_S R_S^4}{\sigma_S} \quad (7)$$

where Equation (7) has been subscripted for the calibration data on the sphere. Since R_S and V_S are measured and σ_S is calculated, there exists a value of the function which describes all system parameters. If R_S and V_S are continuously recorded, then the lumped parameter function $\beta(V)$ becomes continuous. For the calibration track, the sphere radar

cross section is calculated:

$$\sigma_s = \pi r^2 \quad (8)$$

where r = radius of sphere, meters.

It should be noted that equation (8) applies only if the circumference of the sphere lies in the Optical region. The Optical region is defined as that region of size where the ratio of circumference to wavelength is equal to or greater than 10.¹

An identical form of equation (7) is written for the target to be measured:

$$\beta(V_t) = \frac{V_t R_t^4}{\sigma_t} \quad (9)$$

Since the same radar system tracks both sphere and target, $\beta(V_s) = \beta(V_t)$, provided $V_s = V_t$. Substituting $\beta(V_s)$ for $\beta(V_t)$ in equation (9):

$$\frac{R_s^4 V_s}{\sigma_s} = \frac{R_t^4 V_t}{\sigma_t} \quad (10)$$

or:

$$\sigma_t = \frac{R_t^4}{R_s^4} \cdot \sigma_s \quad (11)$$

To solve for σ_t it is necessary to tabulate V_s and R_s on the calibration track. In a similar manner V_t versus R_t are recorded. Since $\beta(V_s)$ must equal $\beta(V_t)$ for $V_t = V_s$, then there exists a value of R_s

¹ See Skolnik [Ref.2] for a discussion of radar diffraction in the Rayleigh, Resonance and Optical regions.

for each value of V_t and R_t . The value of radar cross section of the sphere is known. Thus, target cross section may be found directly for each value of V_t .

III. INPUT DATA BASE

The input data base for both the calibration track and target track was provided to the computer by multi-channel wideband magnetic tape recording. Data extracted from the tape consisted of three signals: boxcar circuit output voltage, range marker ramp voltage, and a trigger pulse. Since this data must be converted to digital form, a brief, examination of the waveforms encountered is relevant.

Consider first the dc level of the boxcar output. Output voltage from the boxcar circuit had a wave shape for a single pulse similar to that shown in Figure (1). The ideal(flat) response was corrupted by the low pass characteristics of the tape recorder and its associated matching networks at input and output. It then became necessary to sample this signal at a zero-crossing, delayed in time to allow sufficient damping. The required delay was determined from the recorder step response and was provided to the computer operator along with other parameters necessary for the analog to digital conversion.

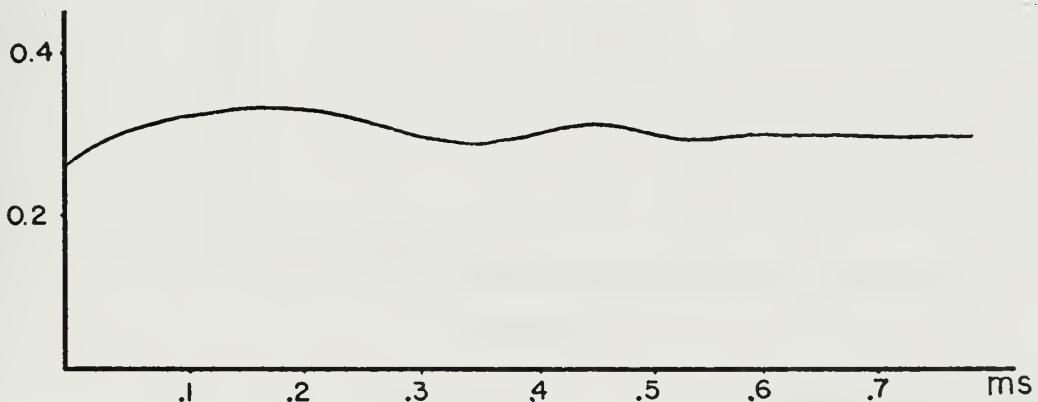


Figure (1)

The radar range marker was a ramp voltage generated by a servo driven potentiometer across a regulated dc power supply. The servo was geared to produce one complete revolution for each two thousand yards range. The servo rotated clockwise for increasing range and counter clockwise for decreasing range. The range ramp voltage was biased slightly negative so that the zero-crossing could be sensed in the computer program, and used to resolve ambiguities between increasing and decreasing ranges. The actual amount of bias is not important and will be discussed in more detail in Section IV. A typical wave form for increasing range is shown in Figure (2). Figure (3) illustrates a decreasing range. The slope of the ramp is proportional to target range rate.

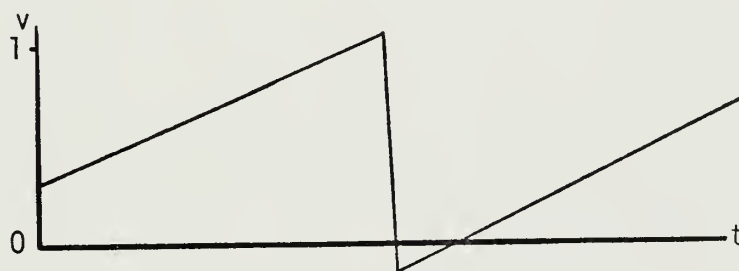


Figure (2)



Figure (3)

The trigger pulse was provided so that the required delay could be set for sampling the boxcar output. This pulse was generated within

the MK 25 Radar and was coincident with the Range Gate Enable signal. The time between pulses was the same as the pulse repetition period of the radar, namely 763 microseconds. A typical trigger pulse is shown in Figure (4).

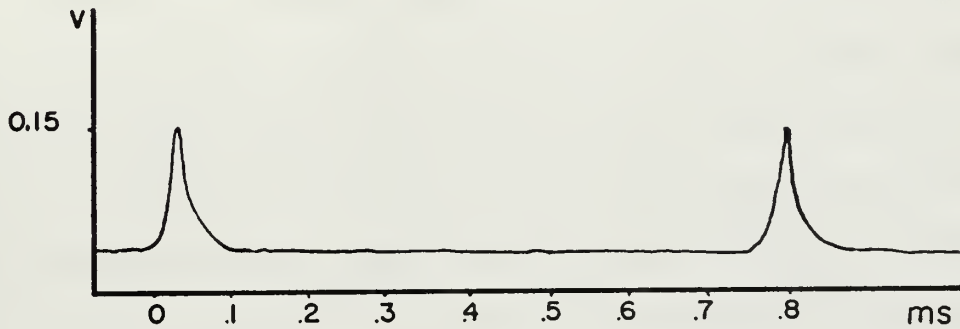


Figure (4)

IV. COMPUTER PROGRAM: SIGMA

A. GENERAL DEVELOPMENT

As described in previous sections, a sphere was tracked and the boxcar circuit output voltage, a function of signal strength, and the corresponding radar range were recorded for each pulse on magnetic tape. Similarly, a target of unknown radar cross section was tracked and the same measurements, boxcar output and range, were recorded. It then became a matter of reading a voltage on the target pulse, and since V_t must equal V_s , the corresponding range to the sphere could be found. Equation (11) was then solved for radar cross section. The most direct scheme to perform these operations with a digital computer would be to store in core memory discrete voltages and ranges for each pulse. In effect, a table would be constructed and a standard look-up routine could be used to extract the data. However, this procedure was neither practical nor economical because of the extreme size of the input data base. A typical calibration track, lasting fourteen minutes, resulted in over one million data points. Assuming that this amount of data could be stored, the time required by the look-up routine to extract one point would be prohibitive.

The need for such a cumbersome table was eliminated by finding the functional relationship between range and boxcar output voltage, described in Equation (3). This was done by calculating the mean signal voltage and mean range for every 1024 pulses, which resulted in a new data set of approximately one thousand points. The functional relationship was then found by constructing a curve from the data set

using a least-squared polynomial fit, with the optimum degree of fit determined by application of the F-Ratio test. The polynomial thus found, together with Equation (11) were entered into a single computational program to generate radar cross section on a pulse to pulse basis.

B. COMPUTATIONAL SCHEME

SIGMA consists of four separate programs written in FORTRAN IV, each containing subprograms written in either FORTRAN IV or META-SYMBOL. Partitioning of the program in this manner facilitated development in that segments of the main program could be selected according to the amount of computer time available. Further, partitioning made possible more rapid isolation of programming errors and shorter turn around time. Extensive use was made of magnetic tape for input and output operations. The use of tape and partitioning was brought about partially by the limited core memory (32K) of the SDS 9300. While appearing to be an inconvenience, the use of tape allowed the results of all data conversions and intermediate calculations to be examined in detail. This was particularly useful in the analysis of noise spikes and their subsequent reduction. If desired, however, one can utilize the overlay structure of the computer and the four separate programs may be compacted into a single segmented routine with essentially one input tape and one output tape.

1. Calibration Data

Signals to be processed are provided to the computer on magnetic tape in analog form having the wave shapes shown in Section III. In order to reduce this data the signals are first converted to digital

form using the COMCOR Ci 5000 analog computer, and the Scientific Data System 9300 digital computer in hybrid configuration. The data is fed into the Ci 5000 from an Ampex Model SP-300 tape recorder, sampled at 1320 cps., digitized into binary words, and written on magnetic tape. This entire operation is performed by the program "A/D".

Voltages written on tape by "A/D" are in the form of 24 bit word integers, scaled by amplification during the sampling process on the Ci 5000. It is desirable to restore this data to its original form in floating point notation for ease of handling and output. Program "DATA SHAPER" performs this function. In addition to converting the voltages from an integer representation to a 48 bit real number, the program applies scaling to account for analog amplifier gain. Further, as the range voltages are converted, the 2000 yard discontinuity is sensed, and radar range is generated directly. These ranges and their corresponding boxcar voltages are then stored and averaged, one record at a time. (One record contains 1024 data pairs.) Both the average values and the pulse to pulse values can be listed by the line printer. Since the record averages are used to derive the functional relationship between R_s and V_s , these are written on magnetic tape.

The last phase of processing on the calibration data is to find the polynomial describing the relation of R_s to V_s . Program "FIT500" is used for this purpose. FIT500 reads in the record averages, selects up to 500 data pairs, and computes a least-squares fit to the degree specified by the namelist input. Since the boxcar output is a quadratic function of signal power, a second degree fit is used. The program also executes an F-Ratio test and calculates errors of the

coefficients generated. The program outputs the polynomial coefficients, the F-Ratio, a tabular listing of the input data with computed dependent variable and error.

This concludes the processing of data for the sphere track. The coefficients computed by FIT500 are used in the program "SIGMAGEN" to calculate radar cross section.

2. Target Data

Boxcar circuit output voltage and radar range for the target being measured is processed in much the same manner as the calibration data. The target signals are first processed by program "A/D" for an analog to digital conversion. This digital output then serves as an input to the program "DATA SHAPER", resulting in a magnetic tape on which is written boxcar circuit output voltage and radar range in yards for each pulse. This tape serves as the input data base for the program "SIGMAGEN", which computes the target radar cross section for each pulse. SIGMAGEN provides a variety of output options, including both magnetic tape and line printer. In addition to the pulse to pulse calculation, the program also averages each record (1024 pulses), and computes an overall mean cross section for selected range intervals. Further, the input tape need not be started at the load point, but may be advanced to any given range by the program. This permits small spans of range to be examined without the need to output an entire tracking run.

C. IMPLEMENTATION

1. Program "A/D"

a. Analog Program

A/D was originally designed to perform an analog to digital conversion on any signal generated within the Ci 5000 with sampling rates up to 12,000 sps. For the conversion necessary in computing radar cross sections, the analog program shown in Figure (5) is used. Throughout this program and all others, boxcar output voltage is labeled S; radar range, R; and range gate trigger, SYNC. Both R and S channels from the tape recorder are fed to separate 50 gain amplifiers on the analog patch board. The gains are not critical but should be chosen so as to provide a working voltage level within the useful range of the Analog Digital Converter unit (ADC) in the SDS 9300. The limits of the ADC are ± 99.99 volts. The maximum tape recorder output voltage is approximately 1 volt RMS. S and R channel amplifier outputs are patched directly to trunks T500 and T501 respectively.

The SYNC channel output is patched through a 1.0 mfd. capacitor to a 100 gain amplifier. Amplifier output is patched to a comparator, the trigger level of which is controlled by a hand set potentiometer. This comparator outputs a logic signal to two delay flops. The first delay flop is used to set the 600 microsecond delay of the logic trigger pulse with respect to the SYNC pulse. The second delay flop is used to adjust the width of the logic trigger pulse. Output from the second delay flop is fed to trunk T211, an interrupt line to the digital computer. Both delay and width can be set by displaying the SYNC and logic trigger pulses on the CRO. If more

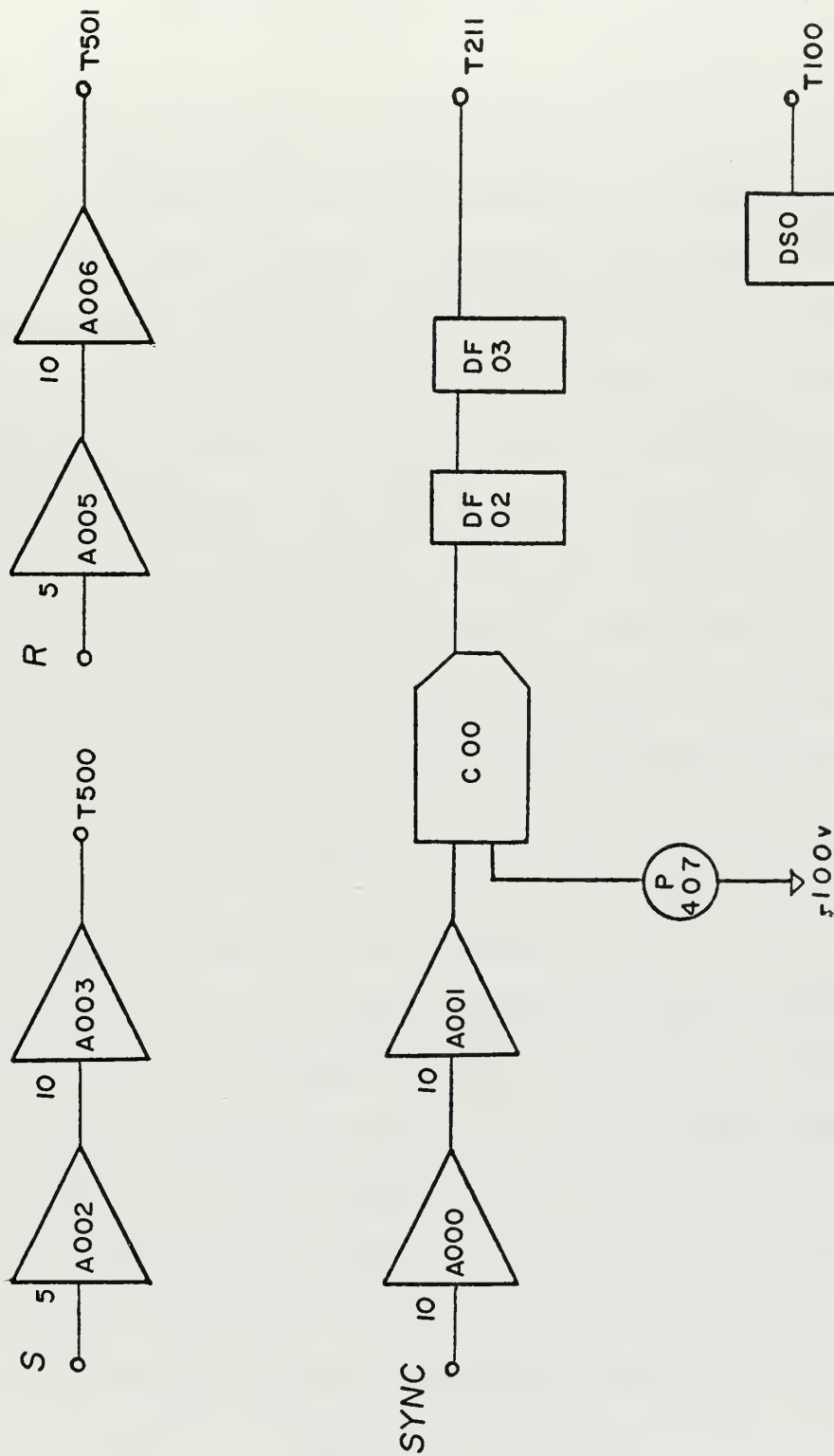


Figure (5)

precision is required, a period counter can be used. To complete the analog program, switch DSØ is wired to trunk T100, a test line to the SDS 9300.

b. Digital Program

The digital portion of A/D consists of a main program and one subroutine written in FORTRAN IV, and two subroutines written in META-SYMBOL. Signals to be converted are fed to the ADC on the trunks specified above. If DSØ is in the ON position then line T100 has a logic level present, the interrupts are enabled, and the sampling and conversion process begins. Values of R and S are stored in array IBUF, dimensioned (2048). When the array is full, the values are written on magnetic tape. This constitutes one record of 1024 values of R and S, written in 24 bit integer form. The actual value of the integer, N, is computed by the SDS 9300 according to the following relation:

$$N = \frac{E \cdot 2^{23}}{100.0} \quad (12)$$

Where E = value of sampled voltage from ADC.

The program will continue to sample, convert, and output to tape one record at a time until a stopping criteria is reached. To stop sampling, DSØ can be switched OFF, or a record limit can be set and entered as namelist input. A/D offers a number of control options. The computer will ask the operator for an option via the teletype. The option number is entered by the operator. The control options are:

Option (1) - enter new namelist data

Option (2) - perform A/D conversion

Option (3) - write "END OF FILE" on tape

Option (4) - rewind tape

Option (5) - skip files

Option (6) - read tape, output to line printer

Option (7) - read tape, output to strip chart recorder

The namelist inputs, entered on the teletype, are:

NREC = total number of records to be written on tape

NCHAN = number of signal channels

NSAMP = 2048/NCHAN

ITAPE = logical unit, magnetic tape drive (integer)

NDEL = number of milliseconds (times 11) delay between
DAC outputs for Option (7).

2. Program "DATA SHAPER"

The output from program "A/D" is in the form of 24 bit integers. The relation between the integer form and the actual value of the voltage sampled is given in Equation (12). The purpose of program "DATA SHAPER" is to convert these integer values to 48 bit real numbers by performing the inverse of the operations indicated in Equation (12), and applying a scale factor to account for gain. Additionally, the program computes the average values for each record. The input data base consists of the magnetic tape output from A/D. This tape is mounted on tape transport logical unit (1). Other input parameters are entered in the namelist using the teletype. The namelist parameters are as follows:

RINT = initial range to the nearest 2000 yard
multiple, expressed as a real number.

SPANR = absolute value of maximum range voltage
minus minimum range voltage.

SSCALE = gain of R channel amplifier used in
program "A/D"

RSCALE = gain of R channel amplifier used in program "A/D".

BIAS = absolute value of bias voltage on the R channel signal.

FIRST = first record the operator desires to examine.

LAST = last record the operator desires to examine.

After the namelist parameters are entered, the program will read in records from the input tape. The records will not be stored until the record specified by FIRST is reached. At this point, 1024 values of S and R are placed in array IBUF. These values are then converted to 48 bit real numbers according to the following relation:

$$E = \frac{N \cdot 100.0}{2^{23} \cdot XSCALE} \quad (13)$$

where: E = input channel voltage

N = 24 bit integer

XSCALE = gain of R/S channel amplifier

The value of the converted S channel voltage is stored in the output array BUF. The value of the R channel is converted to range in yards. As seen in Figure (3), the servo driven potentiometer causes a discontinuity in the range voltage every 2000 yards. At the discontinuity the voltage changes almost instantaneously from a maximum to a minimum for decreasing ranges. Further, a small bias, 0.2 to 0.4 volts, is applied so that the range voltage changes sign at the discontinuity. When the program commences the range is initialized to within a 2000 yard multiple of the range recorded at the start of target track. For example, if the radar started tracking the target at 3600 yards, the

initial range (RINT) would equal 2000 yards. If the track started at 1650 yards, RINT would equal zero. The computer adds or subtracts 2000 yards from RINT each time the discontinuity is sensed. The computer determines the direction of the range increment by comparing the record average just prior to range voltage change from positive to negative, to a record average twenty-five records later. The actual value of range within the 2000 yard interval is computed from the relation,

$$R = \frac{V_R + V_B}{V_S} \times 2000 \quad (14)$$

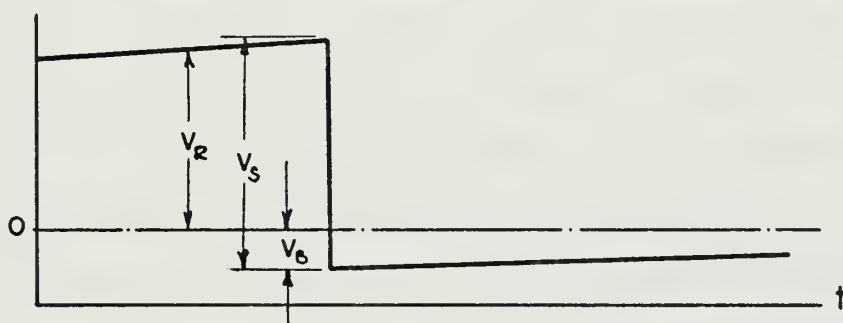


Figure (6)

where V_R = sampled range voltage

V_B = range bias voltage

V_S = range voltage span.

Average boxcar circuit voltage and average range are computed for each record as it is read from the input data tape. These averages are listed by the line printer and stored in core to be written on tape later, if desired. In addition, the pulse to pulse values of voltage and range can be listed on the line printer, record by record by energizing Sense Switch 2. Pulse to pulse values can be written on magnetic tape if a tape is mounted on a tape drive logical unit (2).

3. Program "FIT500"

The purpose of program "FIT500" is to derive the functional relationship between radar range and boxcar output voltage for the calibration track. The core of the program is subroutine LSQPL2, in modified form. Originally the subroutine was developed by D.E. Harrison in November, 1969, to perform a least-squares fit using 100 data points. Additionally, the subroutine performed a Chi-Square "goodness of fit" test and an F-Ratio test. In view of the extreme size of the input data base for program "SIGMA", the subroutine was expanded to handle up to 500 data points. Since core storage in the SDS 9300 is very limited, LSQPL2 had to be modified further by eliminating some of its additional features. The option to weight each data point was removed, as well as the Chi-Square test. The subroutine as it now exists will fit 500 data points and output the coefficients of the functional relation. Other outputs include a tabular listing of the independent variables, the dependent variables, computed dependent variables, and error.

Input data base for FIT500 consists of a magnetic tape mounted on tape drive logical unit (2). This tape should contain the average boxcar voltage and average radar range for each record as generated by the output option in program "DATA SHAPER". The namelist has only two entries:

RECNUM = total number of records on the input tape

KKM = highest degree of fit desired.

Normally, KKM will be set equal to 2 whenever using program "SIGMA", since the relation between range and voltage is quadratic. However, FIT500 can be used alone to compute other functions provided KKM does not exceed 21.

Calibration tracks typically produced approximately 1000 records. FIT500 reads up to 1000 records and then computes the function using every other data pair. In order to read in all records without exceeding core storage, two subroutine arrays, Y and DELY, are used in addition to R and S, the input arrays. Only the data pairs in R and S are used for computation. The Y and DELY arrays are initialized to zero before calling LSQPL2.

4. Program "SIGMAGEN"

The purpose of SIGMAGEN is to compute target radar cross section on a pulse to pulse basis. The input data base consists of the output tape from program "DATA SHAPER", on which are written boxcar output voltage and radar range from the target tracking run. Further, the coefficients of the quadratic relation between boxcar circuit voltage and range for the calibration track must be entered. As explained previously, these are computed by FIT500. The input data tape can be mounted on any tape drive, the logical unit being specified by INTAPE in the namelist.

After namelist parameters and output options have been specified by the operator on the teletype, the program causes the input tape to be read, one record at a time. The functional relation found by FIT500 is only valid over the interval of ranges used in calibration. As computation proceeds, boxcar voltages are read from array BUF, and the calibration range, RCAL, is found. If RCAL exceeds the calibration limits, it is discarded and a new boxcar voltage is read. Only when RCAL is within limits does a calculation for cross section occur. As the values for cross section, SIGMA, are computed, they are stored in the output buffer array DBUF. When the array is full, all 1024 values

of SIGMA and range are averaged. At this point, output can occur depending on the option selected. There are three different outputs from this program. The primary output of interest is the pulse to pulse listing of radar cross section and range. Secondly, the record averages can be printed out. Finally, an overall average SIGMA can be listed. It is conceivable that only a span of specific ranges is of interest, rather than the entire target track. To provide for this, the operator can specify the starting range by RSTART in the namelist. Similarly, RSTOP is entered as the last range of interest. The operator must also enter the radar cross section of the calibration sphere in square meters. Normally, a 6-inch aluminum sphere is used for calibration. In this case SPHR should be set equal to 0.01824.

It may be desirable to examine the target cross section even though the calibrated range is out of bounds. This can be done by executing Option (5) or (6). Output listings will then show all cross sections and ranges, with a minus sign before any range computed out of bounds.

The namelist inputs are:

MINLIM = range calibration, lower bound

MAXLIM = range calibration, upper bound

INTAPE = input tape drive logical unit

OUTAPE = output tape drive logical unit

SPHR = radar cross section, calibration sphere, meter²

B1,B2,B3 = coefficients of quadratic in ascending order

RSTART = first range in span of interest

RSTOP = last range in span of interest

The following is a list of options:

- Option (1) Output to line printer: mean SIGMA and mean RANGE for each record
- Option (2) Output to line printer: SIGMA and RANGE pulse by pulse
- Option (3) Output to tape and line printer: mean SIGMA and mean RANGE for each record
- Option (4) Output to tape and line printer: SIGMA and RANGE pulse by pulse
- Option (5) Defeat calibration bounds. Output to line printer: SIGMA and RANGE pulse by pulse
- Option (6) Defeat calibration bounds. Output to line printer: mean SIGMA and mean RANGE for each record
- Option (7) Read in new namelist
- Option (8) Stop the program

V. CONCLUDING REMARKS

Although SIGMA provides the ground work for computing radar cross sections on a pulse to pulse basis, there are many extensions and some modifications which would expand the usefulness and facility of dynamic target measurement.

It is recognized that SIGMA, as presently written in four parts, does not represent optimal programming. While partitioning was useful for development, the program could be consolidated by utilizing segmented format in the overlay structure of the SDS 9300. This would also reduce the need for large amounts of digital tape.

An examination of the introduction of noise and subsequent error generation would be relevant. The present equipment and methods for recording the analog tape, which is the basic input to the entire computer program, leave room for improvement. In addition to tape hiss, wow and flutter, and switching transients, a certain amount of noise is introduced by the physical location of the tape recorder with respect to the radar equipment racks. Some consideration should be given to the use of a Dolby Noise Reduction package.

The use of the MK 25 Radar imposes certain restrictions. This radar uses a conical scan and therefore causes the returned signals to be modulated at the scan frequency. While a correlation technique could be used in the computer program to account for scan modulation, a better approach would be to use a monopulse radar. The NIKE-AJAX radar system, for example, could provide a better foundation on which to build an instrumentation range.

Finally, regardless of the radar system used, the computer program could be extended to handle target azimuth, elevation and range rate. Instrumentation on airfoil controls, as well as target attitude should also be included. Armed with these inputs, program "SIGMA" could be interfaced with an Adage Graphics Terminal or similar display device for three-dimensional analysis of target aspect and cross section.

PROGRAM: A/D

PURPOSE: SAMPLES ANALOG INPUT AND CONVERTS TO DIGITAL DATA.
OUTPUTS TO MAGNETIC TAPE, PLUS ADDITIONAL OPTIONS.

SAMPLING RATE: UP TO 12,000 SPS

PREPARED BY R. LINES JAN 1971
MODIFIED FOR SIGMA BY F. MEYETT APR 1971

NAMELIST INPUTS:

NREC =TOTAL NUMBER RECORDS TO BE PLACED ON OUTPUT TAPE
NCHAN =NUMBER SIGNALS TO BE DIGITIZED
NSAMP =2048/NCHAN
ITAPE =LOGICAL UNIT TAPE OUTPUT
NDEL =NUMBER MILLISECS(TIME 11.0) DELAY BETWEEN DAC
OUTPUTS FOR OPTION (7).

LIST OF OPTIONS:

- (1) CHANGE PARAMETER NAMELIST
- (2) CONVERT AND OUTPUT TO MAG TAPE
- (3) OUTPUT 'END OF FILE' TO TAPE
- (4) REWIND TAPE
- (5) SKIP FILES
- (6) OUTPUT TO LINE PRINTER


```

C      (7) OUTPUT TO ANALOG STRIP CHART RECORDER FROM TAPE.
C      (SENSE SWITCH 1 MUST BE ON FOR CONTINUOUS OPERATION.)
C
C      SENSE SWITCH 1:  ON  -CONTINUOUS OPERATION OPTION (7)
C                      OFF  -SELECT OPTION
C
C      SENSE SWITCH 2:  ON  -OUTPUTS ONLY ONE RECORD TO STRIP CHART.
C                      OFF  -CONTINUOUS OPERATION OPTION (7).
C
C      PROGRAM A/D STARTS HERE
C
C      DIMENSION IBUF(2048,2),LACB(-1:1),MAXBS(-1:1)
C      INTEGER RECNUM
C      NAMELIST NREC, NSAMP, NCHAN, ITAPE,NDEL
C
C      OPTION (1) INPUT NEW NAMELIST
C
C      INPUT(101)
C      LACB(-1)=LACF(IBUF(1,1))
C      LACB(1)=LACF(IBUF(1,2))
C      NWORDS=NSAMP*NCHAN
C      MAXBS(-1)=LACB(-1)+NWORDS-1
C      MAXBS(1)=LACB( 1)+NWORDS-1
C      IND=0
C      IF(SENSE SWITCH 6)2,15
C
C      OPTION (2) CONVERT A TO D  OUTPUT TO TAPE
C
C      NB=1
C      RECNUM=0
C      NEWBUF=LACB(1)
C      MAXB=MAXBS(-1)
C      CALL ADSTART(NCHAN,LACB(-1),NEWBUF,MAX3,RECNUM,115)
C      MAXB=MAXBS(1)
C      IF(TEST(1).GT.0)GO TO 3

```



```

5      CALL ENARLE
10     CONTINUE
11     GO TO 5
      IF(IND.EQ.1)GO TO 90
      IF(TEST(1).GT.0.6R.RECNUM.6E.NREC)CALL DISABLE
      NB=-NB
      NEWBUF=L0CB(NB)
      MAXB=MAXBS(NB)
      IND=1
      CALL BUFFEROUT(ITAPE,1,IBUF(1,(3+NB)/2),NWRDS,IND)
      IF(TEST(1).LT.0.AND.RECNUM.LT.NREC)GO TO 5
      CALL ACST0P
      CALL PROCESS(IBUF,NSAMP,NCHAN,2S)
      OUTPUT(101)RECNUM
      OUTPUT(101)'OPTION=(I1)'
      READ(101,100)N9PT
      FORMAT(I1)
      GO TO(1,2,30,40,50,60,70)N9PT
C
C      OPTION (3)  OUTPUT 'END OF FILE' TO TAPE
C
30     ENDFILE(ITAPE)
      OUTPUT(101)'E0F'
      GO TO 15
C
C      OPTION (4)  REWIND TAPE
C
40     REWIND(ITAPE)
      GO TO 15
C
C      OPTION (5)  SKIP FILES
C
50     OUTPUT(101)'SKIPFILES=(I4)'
      READ(101,101)NF
      FORMAT(I4)
101

```



```

51 DO 55 I=1,NF
52 CALL BUFFERIN(ITAPE,1,IBUF(1,1),1,IND)
53 IF(IND.LT.2)GO TO 52
54 IF(IND.EQ.2)GO TO 51
55 CONTINUE
56 OUTPUT(101)NF
57 GO TO 15

C
C
C
60 OPTION (6) OUTPUT TO LINE PRINTER
61
62 OUTPUT(101)'NUMWORDS TO LIST=(14)'
63 READ(101,101)NW
64 WRITE(101,105)NW,NCHAN
65 FORMAT(' WRITE ' 14 ' WORDS, ' 12 ' AT A TIME')
66 IND=1
67 CALL BUFFERIN(ITAPE,1,IBUF(1,1),NWORDS,IND)
68 IF(IND.EQ.1)GO TO 66
69 GO TO(62,63,64,65)IND
70 WRITE(6,102)
71 FORMAT(1H1)
72 DO 631 I=1,N,NCHAN
73 WRITE(6,104)(IBUF(J,1),J=1,I+NCHAN-1)
74 FORMAT(12A10)
75 CONTINUE
76 GO TO 15
77 OUTPUT(101)'EOF READ'
78 GO TO 15
79 OUTPUT(101)'READ ERR'
80 GO TO 63

C
C
C
81 OPTION (7) OUTPUT TO STRIP CHART RECORDER
82
83 OUTPUT(101)'START ANALOG RECORDER'
84 OUTPUT(101)'TYPE * C/R TO CONTINUE'
85 INPUT(101)

```



```

77 IND=1
   CALL BUFFERIN(ITAPE,1,IBUF,NWORDS,IND)
76 IF(IND.EQ.1)GO TO 76
71 GO TO(71,72,64,74)IND
72 DO 73 I=1,NWORDS
73   IBUF(I,1)=IBUF(I,1)/2**10
   DO 75 I=1,NWORDS,NCHAN
   DO 75 J=1,NCHAN
   CALL DAC(J,IBUF(I+J-1,1))
   N=NDEL
   CALL DELAY
   IF(SENSE SWITCH 2) 15,75
75   CONTINUE
   IF(SENSE SWITCH 1)77,15
74   OUTPUT(101)'READ ERROR'
   GO TO 72
90   CALL DISABLE
   CALL ADSTOP
   OUTPUT(101)'RATE ERR',RECNUM
   GO TO 15
END

```

```

SUBROUTINE PROCESS(IB,NS,NC,IS)

```

```

N=50000
CALL DELAY
30 IF(TEST(1).LT.0)GO TO 30
   IF(TEST(2).GT.0)RETURN
   RETURN IS
END

```

```

$ADSTART PZE          9SETUPN
          BRM          6
          PZE          6

```


NCH	PZE	ENDBRM
RUF	PZE	O4C
NEWBUF	PZE	SV040
MAXB	PZE	INTBRM
RECNUM	PZE	O52
NEXL8C	PZE	SV052
	LDA	*NCH
	XVA	INCR
	STA	=COMM
	LDA	(5,1)
	XVA	COML8C
	STA	*NCH
	LDA	15
	LLSA	=COMM
	ADD	O,1
	STA	CONTR
	STA	*BUF
	LDA	COMM
	STA	*MAXB
	LDA	MAX
	STA	, NFULL
	SKR	\$-1
	BRU	O34001
	EGM	CONTR
	P9T	ADSTART
	BRR	ADFASST
INTBRM	BRM	ENDAD
ENDBRM	BRM	
SV040	PZE	
ENDAD	PZE	

DIR	034001
HLT	CENTR
ESM	
POT	
EIR	
BRC	*ENDAD
\$ADSTOP PZE	
LDA	SVO40
STA	O40
LDA	SV052
STA	O52
STZ	*C0ML9C
MPQ	ADSTOP
BRR	ADSTOP
C0ML9C PZE	
\$ADFAST PZE	
DIR	SVAB
STD	NFULL
SKN	NXTBUF
BRU	INCR
LDP	C0MM
ADD	C0MM
STA	INCR
ADD	MAX
SKL	NFULL
STB	SVAB
LDP	
EIR	
BRC	*ADFAST
LDA	*NEWBUF
STA	C0MM
LDA	*MAXB
STA	MAX
SKR	NFULL
BRU	\$-1
NXTBUF	

MP0	*RECNUM
LDP	SVAB
EIR	
BRC	*NEXLOC
RES	33
PZE	
PZE	
RES	2
DATA	6,0
PZE	
PZE	
END	

CUMM
CANTR
MAX
SVAB
INCR
NFULL
SV052

PROGRAM: DATA SHAPER

PREPARED BY F.E. MEYFTT APR 1971

THIS ROUTINE CONVERTS THE DATA TAPE VOLTAGES TO SIGNAL STRENGTH AND RADAR RANGE, AND WRITES THIS DATA ON TAPE. THE INPUT DATA TAPE MAY BE ADVANCED TO START AT SOME RECORD OTHER THAN THE FIRST BY SETTING 'FIRST' EQUAL TO THE DESIRED STARTING RECORD. IN A SIMILAR MANNER THE INPUT DATA TAPE MAY BE STOPPED BY ENTERING THE LAST RECORD NUMBER EQUAL TO 'LAST'. 'FIRST' MUST BE GREATER THAN 1.

OUTPUTS: IF END OF FILE IS ENCOUNTERED ON THE INPUT TAPE THE TOTAL NUMBER OF RECORDS AND TOTAL NUMBER OF DATA POINTS IS LISTED ON THE TYPEWRITER.

AVERAGE SIGNAL STRENGTH AND AVERAGE RADAR RANGE ARE OUTPUT TO THE PRINTER AS WELL AS RECORD NUMBER FOR EACH RECORD AS IT IS READ.

ON COMMAND AN ENTIRE RECORD MAY BE PRINTED OUT.

ON COMMAND THE AVERAGE SIGNAL STRENGTH AND RADAR RANGE MAY BE OUTPUT TO MAGTAPE(1).

ON COMMAND MAGTAPE(1) MAY BE READ BACK AND PRINTED OUT.


```

C      INPUT(101)
C      ADVANCE TAPE TO FIRST RECORD
C
C      Z=FIRST-1
D0 999 J=1,Z
I=1
CALL BUFFERIN (1,1,IBUF,2048,I)
998 IF(I.EQ.1) GO TO 998
GO TO (998,999,999,999) I
999 CONTINUE
COUNT=20
RAVE(1)=2000.0
M=1
K=0
RECNUM=0
1 IF(SENSE SWITCH 1)100,5
5 I=1
READ 99L RECORD,FILL BUFFER
C
C      CALL BUFFERIN(1,1,IBUF,2048,I)
6 IF(I.EQ.1) GO TO 6
GO TO (6,8,100,7) I
7 OUTPUT(101)'ERROR READ'
8 J=1
C
C      CONVERT SIGNAL (ECTAL) TO SIGNAL (FLOATING POINT)
C
9 BUF(J)=1.0-(IBUF(J)*100.0/2**23)/SSCALE
J=J+1
C
C      CONVERT RAMP VOLTAGE (ECTAL) TO RANGE (FLOATING POINT)
C
VOLTSR=(IBUF(J)*100.0/2**23)/RSSCALE

```



```

C      RNEW=((V0LTSR+BIAS)/SPANR)*2000.0
C      X=RAVE(1)-RINT
C
C      TEST FOR 2000 YD. MARK/RANGE INCREASING
C
C      IF((V0LTSR.LT.0.0).AND.(X.GT.1000.0).AND.(K.EQ.1)) GO TO 50
C
C      TEST FOR 2000 YD. MARK/RANGE DECREASING.
C
C      IF((V0LTSR.GT.0.0).AND.(X.LT.50.0).AND.(K.FQ.1)) GO TO 55
C
C      10 BUF(J)= RINT+RNEW
C      J=J+1
C      IF(J.GE.2049) GO TO 60
C      GO TO 9
C      50 RINT=RINT+2000.0
C      K=0
C      COUNT=0
C      GO TO 10
C      55 RINT=RINT-2000.0
C      K=0
C      COUNT=0
C      GO TO 10
C
C      STPP RECORD NUMBER,COUNTER
C
C      60 RECNUM=RFCNUM+1
C      M=RECNUM
C      IF(M.GE.LAST) GO TO 100
C      COUNT=COUNT+1
C      IF(COUNT.EQ.25) K=1
C
C      COMPUTE AVERAGE SIGNAL AND RANGE
C
C      SSUM=0.0
C      DO 70 KK=1,2047,2

```



```

SSUM=SSUM+BUF(KK)
70 CONTINUE
RSUM=0.0
DE 71 KK=2,2048,2
RSUM=RSUM+BUF(KK)
71 CONTINUE
SAVE(M)=SSUM/1024.0
RAVE(M)=RSUM/1024.0
WRITE(6,72) RECNUM,SAVE(M),RAVE(M), K
72 FORMAT(I4,5X,F11.4,5X,F11.4,5X,I4)

C
C
C
SELECT OPTION TO PRINT ALL POINTS IN RECORD

IF(SENSE SWITCH 2) 73,80
73 WRITE(6,74) RECNUM
74 FORMAT('RECNUM',I4)
DE 77 I=1,2048,2
WRITE(6,76) (BUF(M),M=I,I+1)
76 FORMAT(F11.4,10X,F11.4)
77 CONTINUE
78 WRITE(6,79) RECNUM
79 FORMAT('END RECNUM',I4)
80 N=1

C
C
C
OUTPUT ALL CONVERTED DATA POINTS TO TAPE(2).

CALL BUFFEROUT(2,1,BUF,4096,N)
81 IF(N.EQ.1) GO TO 81
IF(N.EQ.4) GO TO 82
GO TO 1
82 OUTPUT(101)'ERROR WRITTEN'
GO TO 1
100 OUTPUT(101)'END OF FILE'
NUMPTS=RECNUM*1024
OUTPUT(101)RECNUM,NUMPTS

```



```

END FILE 2

REWIND 2
REWIND 1

C
C
C
SELECT OPTION TO OUTPUT AVERAGES TO TAPE(1).

IF(SENSE SWITCH 3) 110,101
101 OUTPUT(101)'REMOVE TAPE,UNIT(1), MOUNT TAPE,UNIT (3)',
  OUTPUT(101)'TYPE * C/R TO CONTINUE',
  INPUT(101)
WRITE(3) (SAVE(J),RAVE(J),J=1,RECNUM)
END FILE 3

C
C
C
REWIND 3

SELECT OPTION TO RECORD CHECK TAPE(1).

IF(SENSE SWITCH 4) 110,104
104 DO 105 J=1,RECNUM
  SAVE(J)=0.0
  RAVE(J)=0.0
105 CONTINUE
  READ(3) (SAVE(J),RAVE(J),J=1,RECNUM)
  WRITE(6,106) (SAVE(J),RAVE(J),J=1,RECNUM)
106 FORMAT(F11.4,10X,F11.4)
110 STOP
END

```


PROGRAM: FIT500

PREPARED BY F.E. MEYETT MAY 1971 FOR SIGMA

PURPOSE: READS UP TO 1000 DATA PAIRS OF RANGE (R) AND SIGNAL (S)
AND COMPUTES THE FUNCTIONAL RELATION WITH SIGNAL (S) AS
THE INDEPENDENT VARIABLE. EVERY OTHER DATA PAIR IS USED
FOR THE LEAST SQUARES FIT SO THAT A MAXIMUM OF 500
POINTS MAY BE FITTED.

REMARKS: MOUNT INPUT DATA TAPE ON LOGICAL UNIT (2).

NAMelist INPUTS:
RECNUM =TOTAL NUMBER OF RECORDS ON INPUT DATA TAPE
KKM =HIGHEST DEGREE OF FIT DESIRED. (SET KKM=2 FOR
SIGMA.)

SUBROUTINE: LSQPL2

A. IDENTIFICATION:
TITLE: LEAST SQUARES POLYNOMIAL FITTING
CATEGORY: CURVE FITTING

PROGRAMMED BY D.E.HARRISON, NOV 1969.


```

C      INPUT(101)
C      NUMPTS=RFCNUM/2
C
C      READ INPUT DATA TAPE
C
C      READ(2) (S(I),R(I),Y(I),DELY(I),I=1,NUMPTS)
C
C      RECORD CHECK
C
C      WRITE(6,50) (S(I),R(I),Y(I),DELY(I),I=1,NUMPTS)
C      50 FORMAT(F11.4,5X,F11.4,5X,F11.4,5X,F11.4)
C
C      ZERO Y AND DELY ARRAYS
C
C      DO 10 J=1,NUMPTS
C      Y(J)=0.0
C      DELY(J)=0.0
C      10 CONTINUE
C      100 WRITE(6,100) RECNUM,NUMPTS,KKM
C      100 FORMAT(5X,'RECNUM=',I4,5X,'NUMPTS=',I3,5X,'KKM=',I1)
C      CALL LSQPL2(NUMPTS,KKM,S,R,Y,DELY,B,SB,TITLE)
C      REVIND 2
C      STOP
C      END
C
C      SUBROUTINE LSQPL2(M,KM,X,F2,Y,DELY,B,SB,TITLE)
C      INTEGER TITLE(10)
C      REAL X(1),F2(1),Y(1),DFLY(1),B(1),SB(1),
C      X FM,FMR,PXF,PXP,XPPM,PPXPP,XP,ALPHA,BETA,PPXF,FBAR,XBAR,
C      XF(500),P(500),PM(500),S(500),ST(500),A(21,21),T(500)
C      1,SIG2,SIG3,SJMEV2,FLEV,F2BAR,SQ,FMF,FMKF,AM,CHI
C      DO 1 I=1,21
C      DO 1 J=1,21
C      1 A(I,J)=0.0

```



```

A(1,1)=1.0
A(2,2)=1.0
PBAR=0.0
SUMEV2=0.0
FM=M
FMR=1.000/FM
FBAR=C.0
YBAR=0.0
DO 10 I=1,M
W=FMR
PM(I)=SQRT(W)
F(I)=F2(I)*PM(I)
SUMEV2=SUMEV2+F2(I)
FBAR=FBAR+F(I)*PM(I)
10 XBAR=XBAR+X(I)*W
T(1)=FBAR
A(2,1)=-XBAR
PXF=C.0
XP=C.0
F2BAR=SUMEV2/FM
SUMEV2=C.00
DO 20 I=1,M
SUMEV2=SUMEV2+W*(F2(I)-F2BAR)**2
P(I)=(X(I)-XBAR)*PM(I)
PXF=PXFP(I)*F(I)
20 PXD=PXPD(I)*P(I)
NFM=FM+C.00001
T(2)=PXF/PXP
PNXPM=1.000
S(1)=PNXPM
KMP=IABS(KM)+1
E(1)=T(1)*A(1,1)+T(2)*A(2,1)
E(2)=T(2)*A(2,2)
DO 1000 K=2,KMP
CHI=0.

```



```

KM1=K-1
KM2=K-2
IF (KM2.LE.0) GO TO 200
XPXP=0.0
YXPY=0.0
B(K)=0.0
DO 50 J=1,M
  XP=X(J)*P(J)
  XXP=X*XP+XP*P(J)
50 XXPY=Y*XPY+XP*P(J)
  ALPHA=X*Y*P/PPXP
  BETA=XP*XPY/PPXPY
  PPXF=0.0
  PPXPP=0.0
DO 100 I=1,M
  PT=P(I)
  P(I)=(X(I)-ALPHA)*P(I)-BETA*PM(I)
  PPXF=PPXF+P(I)*F(I)
  PPXPP=PPXPP+P(I)*P(I)
100 PM(I)=PT
  T(K)=PPXF/PPXPP
  PMXPY=PPXP
  PXP=PPXPP
  A(K,1)=-ALPHA*A(KM1,1)-BETA*A(KM2,1)
  A(K,KM1)=A(KM1,KM2)-A(KM1,KM1)*ALPHA
  A(K,K)=1.0
  IF (K.LE.3) GO TO 150
DO 120 I=2,KM2
120 A(K,I)=A(KM1,I-1)-ALPHA*A(KM1,I)-BETA*A(KM2,I)
150 DO 160 I=1,K
160 P(I)=B(I)+T(K)*A(K,I)
200 SIG3=0.0
DO 220 I=1,M
  SQ=B(K)
  KK(K)=K-1

```



```

D9 230 IQ=1,KKQ
KMIQ=K-IQ
230 SQ=X(I)*SQ+B(KMIQ)
Y(I)=SQ
DELY(I)=Y(I)-F2(I)
220 SIG3=SIG3+K*DELY(I)**2
FMYKF=MYFY-K
SIG2=SIG3*FM/FMYKF
FLFV=(SUMEV2-SIG3)/SIG2
SUMEV2=SIG3
S(K)=PXP
D9 240 I=1,K
240 ST(I)=SIG2/S(I)
D9 300 I=1,K
SR(I)=C.O
D9 250 J=1,K
250 SB(I)=SB(I)+ST(J)*A(J,I)**2
300 SB(I)=SQRT(SB(I))
IF(KY.GT.O)G9 T9 301
CONTINUE
IF(K.LT.KMP)G9 T9 1000
301 CONTINUE
WRITE(6,9510) (TITLE(I),I=1,10)
9510 FORMAT(1H1,20X,10A8,/,/,20X,'COEFFICIENTS OF THE POWER SERIES EXPAN
XION',/,20X,'Y(X)=B(1)+B(2)*X+B(3)*X**2+B(4)*X**3+...,'/,/)
WRITE(6,9520) ((I,SB(I)),I=1,K)
9520 FORMAT(6(' 3(' ,I2,' )=' ,1PE12.5))
WRITE(6,9530)
9530 FORMAT(/,/,20X,'ESTIMATES OF ERROR FOR THE COEFFICIENTS',/,/)
WRITE(6,9540)((I,SB(I)),I=1,K)
9540 FORMAT(6(' ERRB(' ,I2,' )=' ,1PE9.3))
WRITE(6,9570) SIG3,FLFV
9570 FORMAT(/,/,3X,'SUM SQ DEV =' ,1PE10.3,10X,'F-RATIO =' ,1PE10.3)
D9 25 IRI=1,
25 CHI=CHI+DELY(IRI)*DELY(IRI)/ABS(Y(IRI))

```



```

WRITE(6,1111)CHI,FMKF
1111 FORMAT('O CHISQ=',1PE11.3,7X,'DEG 9F FREEDOM =',OPF4.0)
WRITE(6,9550)
9550 FORMAT('//, ' I      R(I)      S(I)DATA      S(I)CURVE
      XLY(I)',//)
WRITE(6,9560) (I,X(I),F2(I),Y(I),DELY(I),I=1,M)
9560 FORMAT(14,2X,OPF11.4,2X,1PE15.7,2X,1PE15.7,2X,1PE15.7)
1000 CONTINUE
      RETURN
      END
DE

```


PROGRAM: SIGMAGEN

PREPARED BY F.F. MEYFIT APR 1971 FOR SIGMA

PURPOSE: COMPUTATION OF RADAR CROSS SECTION FROM A MAGNETIC TAPE
INPUT. TAPE MUST HAVE BEEN PREVIOUSLY PREPARED USING SUBROUTINE
'BUFFERIN'.

OUTPUT FLEXIBILITY IS PERMITTED BY THE USE OF OPTIONS LISTED BELOW:

- OPTION (1) OUTPUT TO LINE PRINTER: MEAN SIGMA, MEAN RANGE FOR
EACH RECORD.
- OPTION (2) OUTPUT TO LINE PRINTER: SIGMA AND RANGE POINT BY
POINT.
- OPTION (3) OUTPUT TO TAPE AND LINE PRINTER: MEAN SIGMA
AND MEAN RANGE FOR EACH RECORD.
- OPTION (4) OUTPUT TO TAPE AND LINE PRINTER: SIGMA AND RANGE
POINT BY POINT.
- OPTION (5) DEFEAT CALIBRATION BOUNDS LIMIT. OUTPUT TO LINE
PRINTER: SIGMA AND RANGE, POINT BY POINT. A MINUS
SIGN PRECEDING RANGE INDICATES 'COMPUTED OUT OF
BOUNDS'.
- OPTION (6) DEFEAT CALIBRATION BOUNDS LIMIT. OUTPUT TO LINE
PRINTER: MEAN SIGMA AND MEAN RANGE FOR EACH RECORD.
- OPTION (7) READ IN NEW NAMELIST DATA.
- OPTION (8) STOP THE PROGRAM.

[illegible]


```

C      READ IN ONE RECORD
C
11  IND=1
12  CALL BUFFERIN(INTAPE,1,BUF,4096,IND)
13  IF(IND.EQ.1) GO TO 12
14  GO TO (12,14,18,13)IND
15  OUTPUT(101)'END OF FILE'
16  GO TO 19
17  OUTPUT(101)'ERROR READ'
18
19  SET BUFFER SUBSCRIPT COUNTER
20
21  J=1
22  IF(J.GE.2049) GO TO 11
23  STGT=BUF(J)
24  J=J+1
25  RTGT=BUF(J)
26
27  TEST FOR STARTING RANGE
28
29  IF(RTGT.GE.RSTART) GO TO 16
30  J=J+1
31
32  TEST FOR END OF INPUT RECORD
33
34  IF(J.LT.2049) GO TO 15
35  GO TO 11
36
37  TEST FOR END RANGE
38
39  IF(RTGT.LE.RSTOP) GO TO 17
40  WRITE(6,101)SLAVE,RTAVE
41  101 FORMAT(//,5X,'OVERALL MEAN SIGMA=',F9.2,5X,'OVERALL MEAN RANGE=',
42  F9.2,/)
43  GO TO 90

```



```

SSUM=SSUM+DBUF(I)
31 CONTINUE
RSUM=0.0
DO 32 I=2,2048,2
  RSUM=RSUM+ABS(DBUF(I))
32 CONTINUE

C
C
C   COMPUTE RECORD AVERAGES
C
  SIGAVE=SSUM/(1024.0-COUNT)
  RTGAVE=RSUM/1024.0
  SIGRT=SIGRT+SIGAVE
  RTGRT=RTGRT+RTGAVE

C
C
C   COMPUTE OVERALL MEANS
C
  STAVE=SIGRT/AINT(RECNUM)
  RTAVE=RTGRT/AINT(RECNUM)
  COUNT=0.0

C
C
C   OUTPUT OPTIONS BEGIN HERE
C
  GO TO (40,50,60,70,50,40)N9PT
40 WRITE(6,102)RECNUM,SIGAVE,RTGAVE
102 FORMAT(3X,'RECORD N9.='',I4,5X,'MEAN SIGMA='',F9.2,5X,'MEAN RANGE='',
      XF9.2)
41 N=0
  GO TO 15
50 WRITE(6,103) RECNUM
103 FORMAT(//,'START RECORD NUMBER',I4,/)
51 WRITE(6,104)
104 FORMAT(5X,'SIGMA RANGE',/)
  DO 53 K=1,2048,2
52 WRITE(6,105) (DBUF(N),N=K,K+1)
105 FORMAT(3X,F9.2,6X,F9.2)

```



```

53 CONTINUE
54 WRITE(6,106) RECNUM
106 FORMAT(//,'END RECORD NUMBER',I4,/)
      GO TO 40
60 WRITE(8UTAPE) SIGAVE,RTGAVE
      GO TO 40
70 IND=1
  CALL BUFFEROUT(8UTAPE,1,DBUF,4096,IND)
71 IF(IND.EQ.1) GO TO 71
  IF(IND.EQ.4) GO TO 72
      GO TO 50
72 OUTPUT(101)'ERROR WRITTEN'
      GO TO 50
90 REWIND(1NTAPE)
  END FILE(8UTAPE)

      REWIND(8UTAPE)
      LOOP BACK TO INPUT OPTION

      GO TO 5
99 STOP
END

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C
C
C

LIST OF REFERENCES

1. Naval Missile Center Technical Memorandum RM-67-44, An Operational Method For Measuring Radar Cross Section Of An Airborne Target, by F.T. Cunningham, 30 August 1967.
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<p>This paper describes the design and use of SIGMA, a computer program for the calculation of radar cross section of a dynamic target on a pulse to pulse basis, using the MK 25 Fire Control Radar. The program is written specifically for use on the Scientific Data Systems 9300 computer in FORTRAN IV, but is readily adapted to other data processing systems. The input data base is composed of magnetic tape recordings of instrumented radar range and signal strength. Outputs include target cross section and range, and mean cross section and range in printed tabular listing, in graphical form, and on digital magnetic tape.</p>			

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